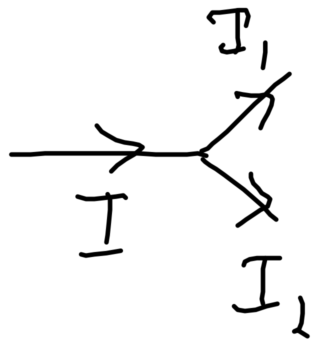
Kirchhoff's Laws:

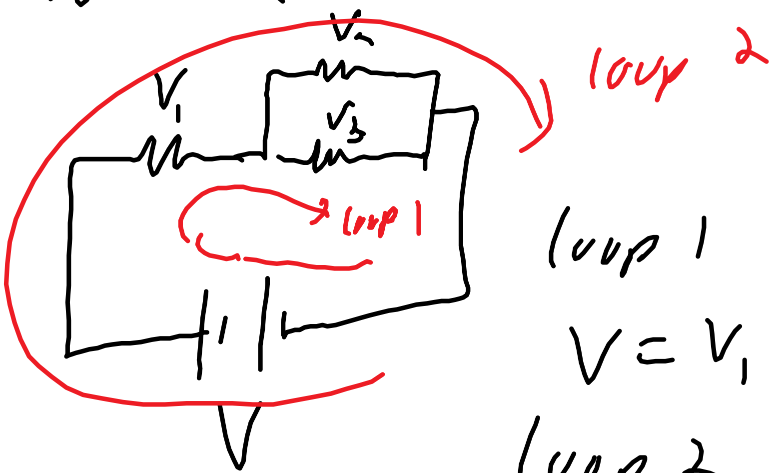
Junction Law

$I = I_1 + I_2$



Loop Law

Voltages around a loop add to zero



$V - V_1 - V_3 = 0$

loop 1

$V = V_1 + V_3$

loop 2

$V = V_1 + V_2$

$V_3 = V_2$ ← voltages in parallel are equal

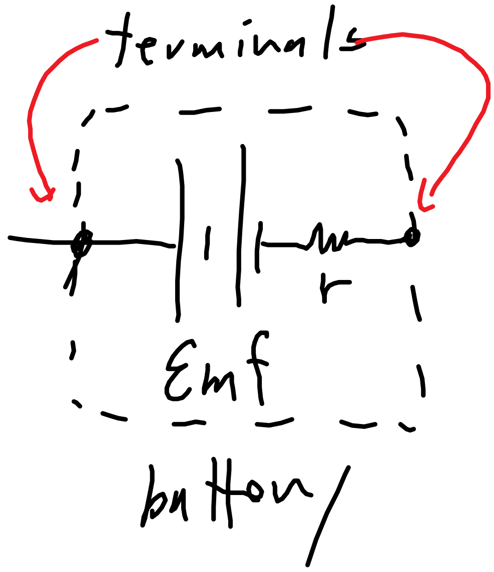
resistance $R = \frac{V}{I}$

Internal resistance, r

- when lots of current flows out of a battery, they get hot

Where does this heat come from?

- model this process as being like a resistor inside the battery / Power supply.



Emf - stands for electro-motive force, Not a force

- electric potential (V)

with no current, I.

Terminal Voltage, V_t - Potential (V) when current is flowing.

$$Emf = V_t + Ir$$

↑ if the current flows backwards, change to −

↑ internal resistance

Eg.

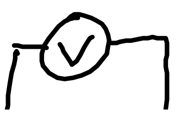
You connect a 1.5 V battery to a 30.0 ohm resistor and connect an ammeter and voltmeter across the resistor.

a) Draw a circuit diagram, include internal resistor, r and the meters.

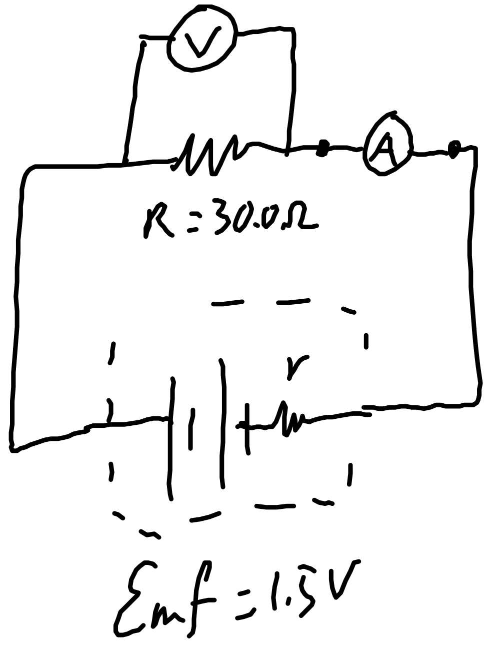
b) If the ammeter reads 40.0 mA and the voltmeter reads 1.20 V, determine r.

c) If you connect a 20.0 ohm resistor in parallel to the 30.0 ohm resistor, determine the new terminal voltage.

a)



a)



b) $Emf = V_t + Ir$

$1.5V = 1.2V + 0.04A\, r$

$r = \frac{0.3}{0.04} = \boxed{7.5\Omega}$

c) $I = \frac{Emf}{R_T}$

$\frac{1}{R_{T_1}} = \frac{1}{20} + \frac{1}{30}$

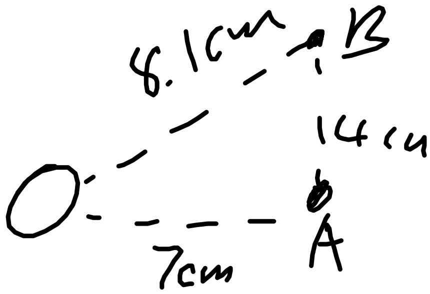
$R_{T_1} = 12\Omega$

$I = \frac{1.5V}{12\Omega + 7.5\Omega} = 0.0769A$

$V_T = Emf - Ir$

$1.5V - 0.0769A(7.5\Omega)$

$$= \boxed{0.92\,V}$$



$Q = 5.5\,\mu C$

$$V_A - V_B$$

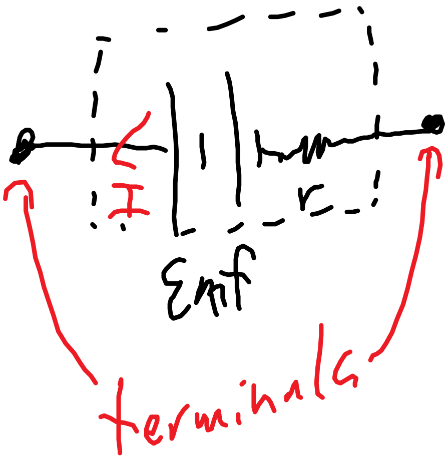
$$\left(\frac{KQ_1}{r_A} - \frac{KQ_1}{r_B}\right) + \left(\frac{KQ_2}{r_A} - \frac{KQ_2}{r_B}\right)$$

$$2 \times \frac{9\times10^9 * 5.5\times10^{-6}}{}\left(\frac{1}{0.07} - \frac{1}{0.081}\right)$$

$$= \boxed{1.9\times10^5\,V}$$

Internal Resistance, r
R is resistance, R=V/I

Big Idea: when current flows out of a battery or power supply, they get hot. We can model this process as being like a resistor inside, r. This is the internal resistance. (not really a resistor but heat is produced like a resistor)



Emf - electro motive force
- not a force
- the potential of the battery with no current flowing!
- Voltage

V - terminal voltage

- voltage across the battery when current flows.

$V_t = Emf$ no current

$V_t = Emf - Ir$

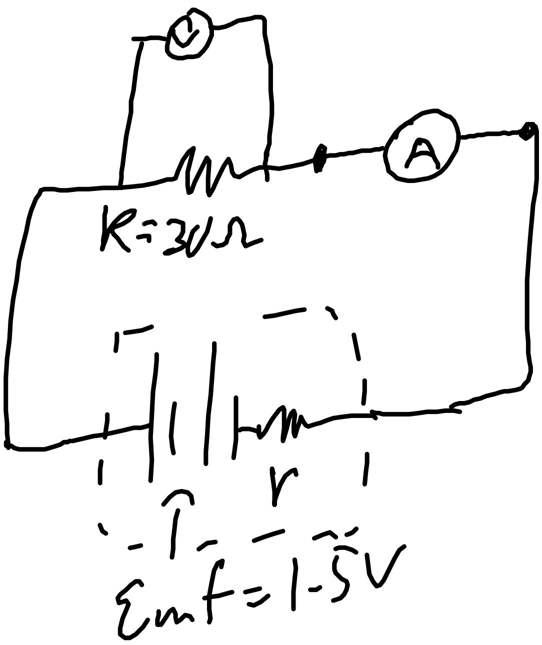
↑ energy lost in battery as heat

if the current runs backwards, flip to +.

Eg. A 1.50V battery is connected to a 30.0 ohm resistor. An ammeter and voltmeter are connected to measure the current through and voltage across the resistor.

a) Draw the circuit diagram with ammeter, voltmeter and internal resistance, r.
b) If r=0, then the current should be:
c) If you measure the current to be 40.0 mA, what is the terminal voltage and internal resistance?
d) If you connect a 20.0 ohm resistor in parallel

with the 30.0 ohm resistor, what is the terminal voltage of the battery (assume constant internal resistance).



b) if no internal resistance

then $I = \frac{V}{R} = \frac{1.5V}{30\Omega} = 0.050A$

50.0 mA

c) $I = 40mA$ $r \neq 0$

$V_t = IR = 0.040A \times 30.0\Omega$

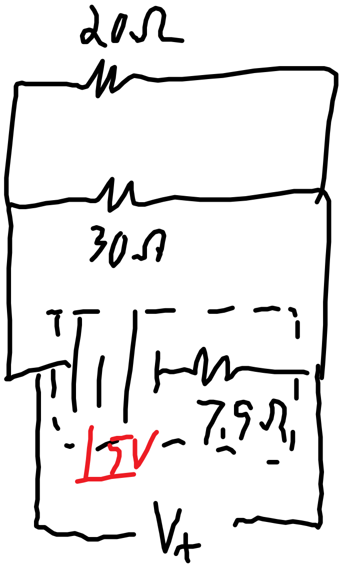
$= $ **1.20 V**

$$Emf = V_t + Ir$$

$$1.5\,V = 1.20\,V + 0.040\,A\; r$$

$$\boxed{r = 7.5\,\Omega}$$

d)



$$V_t = Emf - Ir$$

$$Emf = 1.5\,V$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{1}{30} + \frac{1}{20} = \frac{2}{60} + \frac{3}{60}$$

$$\frac{1}{R_T} = \frac{5}{60} \quad R_T = \frac{60}{5}$$

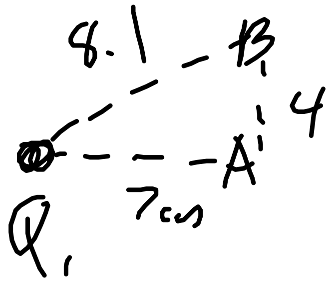
$$\underline{R_T = 12\,\Omega}$$

$$I = \frac{V}{R} = \frac{1.5\,V}{12\,\Omega + 7.5\,\Omega} = \boxed{0.0769\,A}$$

$$V = IR = \boxed{0.923\,V}$$

$$V_T = IR = \boxed{0.923\,V}$$

$$V = \frac{KQ}{r}$$

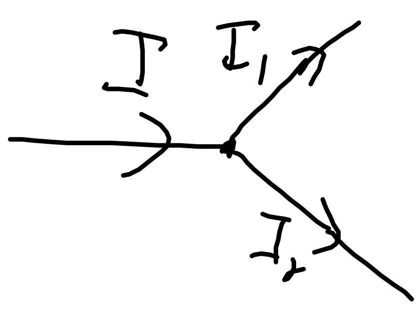


$$V_B - V_A = 2\left[KQ\left(\frac{1}{0.081} - \frac{1}{0.07}\right)\right]$$

Potential = V

Potential energy = E_e

Kirchhoff's Laws:
Junction Law:
Current in to a junction = current out



$$I = I_1 + I_2$$

Loop Law:
Voltages around a loop add to zero.
Voltages in series add up
Voltages in parallel are equal

loop 1

$$V = V_1 + V_2$$

loop 2

$$V = V_1 + V_3$$

$$\boxed{V_2 = V_3}$$

Internal Resistance, r

What happens when you short circuit a battery? (don't do this, dangerous!)

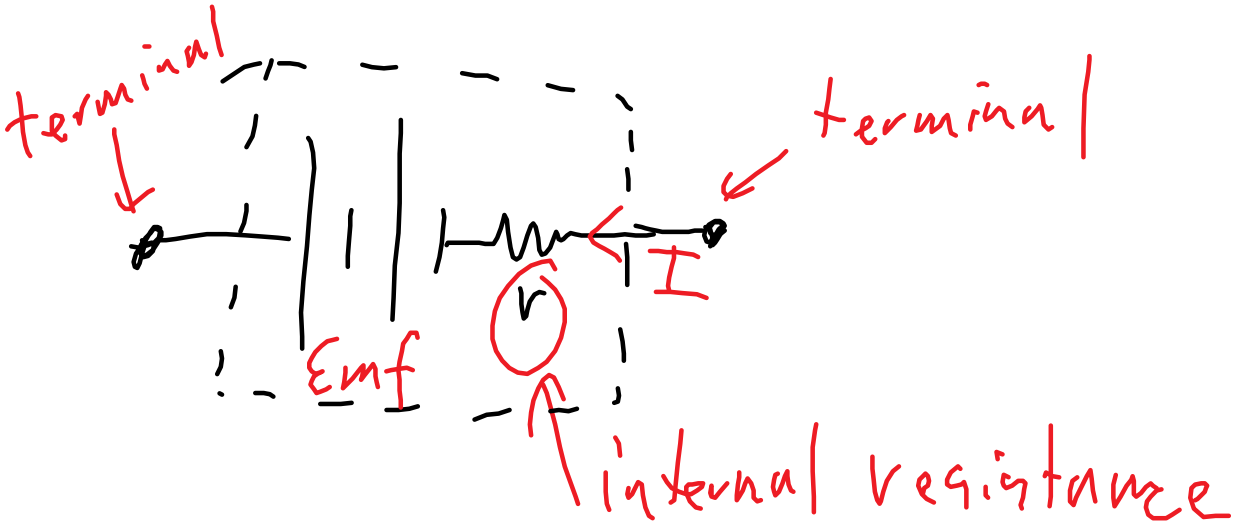
The battery produces lots of current and gets hot. Where does the energy come from?

Think of the process where the terminals react with the solution as producing electrical energy with some heat energy by-product.

Model this process as being like a resistor (gives off heat) inside the battery or power

supply.

The internal resistance, r.



Emf - electromotive force
- not a force
- a voltage
- voltage of battery with **no** current.

V_t - Terminal voltage
- voltage battery with current.

$V_T = Emf$ no current

$$V_t = Emf - Ir$$

I: current through battery

r: internal resistance

- reverse sign if current is reversed,
- recharging

Eg. A 1.50V battery is connected to a 30.0 ohm light bulb. An ammeter and voltmeter are connected to measure the current through and voltage across the bulb.

a) Draw the circuit diagram with ammeter, voltmeter and internal resistance, r.

b) If internal resistance, r=0, then the current through the light bulb should be:

c) If you measure the current to be 40.0 mA, what is the terminal voltage and internal resistance of the battery?

d) If you connect a 20.0 ohm light bulb in parallel with the 30.0 ohm, which is brighter? What is the terminal voltage of the battery?(assume

constant internal resistance).

e) Repeat d if they are in series.